# The implementation of FMEA for analyzing the risk of natural disaster logistic activities (case study: CSER project childfund international)

**Serli Bombang[1*)]**

[1]Master of Industrial Engineering Student, Universitas Mercu Buana, Jakarta Province, Indonesia

*Corresponding author: sbombang@gmail.com

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***Abstract.*** *Indonesia is a country prone to natural disasters due to its location at the convergence of active tectonic plates. During natural disasters, logistics becomes crucial in emergency response. The aim of this study is to analyze the risks involved in logistics activities during natural disaster emergency response, focusing on the case of Central Sulawesi in 2018. The method used in this research is Failure Mode and Effect Analysis (FMEA). This research is descriptive-exploratory in nature based on interviews and questionnaire distribution. The results indicate eighteen risks occurring during emergency response logistics activities conducted by Childfund International. Calculation results show six critical risks in emergency response logistics activities, namely errors in planning required demand, expired goods, expiration dates too close, closure or absence of goods reception, prolonged accountability report preparation process, and incomplete accountability reports.*

*Keywords: Failure Mode and Effect Analysis, logistics, natural disaster logistics, risk*

## 1. Introduction

Indonesia is classified as a country with a very high frequency of disasters because it is located at the convergence of active tectonic plates, with tropical terrain and climate (Harsono et al., 2018). According to Law No. 24 of 2007 concerning Disaster Management, a disaster is a series of threatening and disruptive events to human and community life caused by natural and human factors, resulting in human, environmental, material, and psychological losses, which can have lasting effects (Putra, 2023). Therefore, when natural disasters occur, causing many people to evacuate and damaging public facilities, the government's responsibility is to manage disaster management from the pre-disaster phase, during the disaster, and post-disaster. The government has the authority and primary goal of protecting the public by implementing appropriate prevention and response measures to mitigate the impact of disasters. One of the steps taken is to establish institutions, bodies, or organizations authorized by the government to address and manage such disasters.

In recent years, Indonesia has experienced various natural disasters in several provinces across the country. One of the largest natural disasters ever to occur was the 7.4 magnitude earthquake that triggered a tsunami and liquefaction on September 28, 2018, in Palu, Sigi, and Donggala (PASIGALA). This event resulted in a significant loss of lives and extensive damage. Based on data from the National Disaster Management Agency (BNPB), the 7.4 magnitude earthquake that caused liquefaction and a tsunami in several areas of Central Sulawesi is summarized in the infographic in Figure 1 (Putra, 2023).

Figure 1, it is shown that the natural disaster that occurred in Central Sulawesi in 2018 resulted in significant losses and claimed thousands of lives among the affected population. The data indicates that there were 4,340 fatalities or missing persons, 172,635 displaced individuals, 4,438 injured, 265 schools damaged, 68,451 houses destroyed, 327 places of worship affected, and other consequences. This disaster occurred at 122 points and was caused by a 7.4 magnitude earthquake, liquefaction, and tsunami.

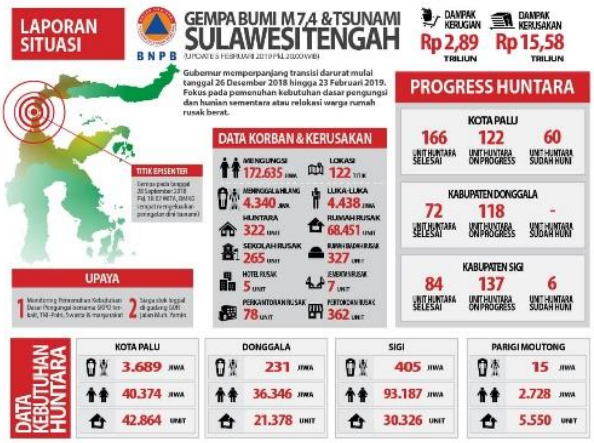


**Figure 1** The Occurrence of the earthquake, liquefaction, and tsunami in Palu, Sigi, and Donggala in 2018.
(Source: BPBD Central Sulawesi)

ChildFund International is one of the international NGOs focused on community welfare, particularly children. However, during natural disasters, ChildFund is always involved in emergency response to provide logistical assistance to disaster victims. During the 2018 natural disaster in Central Sulawesi, ChildFund was one of the NGOs involved in emergency response. ChildFund sets up several tents at evacuation sites focused on the safety and trauma recovery of children who survived the disaster.

Logistics can be defined as the transportation of goods, spare parts, and finished products from suppliers between company facilities and customers with the aim of delivering finished products and various materials in the right quantities and acceptable conditions at the right time, using strategic storage management processes to achieve the lowest total cost. Therefore, logistics management responsibility entails designing and maintaining strategic flow monitoring systems and storage of materials, spare parts, and finished goods to maximize profits for the company (Harsono et al., 2018). Logistics also is defined as a function that emphasizes the movement, including the arrangement of goods movement and material storage throughout its journey along a supply chain from the initial sender to the final customer (Waters, 2023). Another supporting factor contributing to the growth of logistics businesses is the consumer lifestyle in shopping and transactions. In recent years, people have become accustomed to using various shopping apps and making payments through digital payment systems.

Humanitarian logistics is one of the operations involved in following the three stages of Disaster Management: preparation, response, and recovery. Humanitarian logistics involves the process of evacuating people from disaster-stricken areas to safe locations and planning, implementing, and controlling the flow and storage of goods and materials efficiently and cost-effectively, while gathering information from the point of origin to the point of consumption (Boonmee et al., 2017).

During the 2018 natural disaster in Central Sulawesi, several field conditions were encountered during the emergency response phase. These included uneven distribution of logistics due to some easily accessible locations, unfocused evacuation sites that went undetected by existing NGOs, and difficulty in accessing certain areas due to liquefaction, causing public infrastructure such as roads to shift, thus making it challenging for aid providers to reach affected areas. Additionally, there was a lack of oversight by logistics personnel in the disaster response warehouse storage process, primarily due to prolonged inventory, expired stock, poor product quality, limited availability of items in dealer warehouses, distribution time, transportation, and consumer support with facility availability. The resulting uncertainty was one of many problems that logistics had to address, resulting in losses and risks.

Failure Mode and Effect Analysis (FMEA) is a method used to identify, recognize, and address the potential occurrence of failures, issues, errors, and other negative elements (Amalina et al., 2024; Chairany & Hidayatno, 2019). Consistent with what (Penangsang & Basuki, 2024) stated, FMEA is used to determine how components, systems, or processes fail to achieve the goals set in their design. This FMEA method is used to analyze all possible risks arising from an activity. Research

related to Failure Mode and Effect Analysis (FMEA) for risk mitigation has been conducted by many researchers, both in logistics and other fields (Akmal & Kurnia, 2023; Aprianto et al., 2021; Hidayat et al., 2023; Islamey et al., 2023).

Penangsang & Basuki (2024) research aimed at mitigating operational risks using FMEA to solve problems with the construction of new ships at the Surabaya Shipyard, with the results indicating a level of production failure caused by threats related to production failure rates due to imported materials. Meanwhile, Amalina et al. (2024) research analyzed the causes of risk in the blood supply chain during the COVID-19 pandemic using the Supply Chain Operations Reference (SCOR) Model and Failure Modes and Effects Analysis (FMEA), identifying 34 risks and 29 risk factors. Akmal & Kurnia (2023) conducted operational warehouse risk analysis using FMEA, identifying five critical risks: input control, inventory control, output control, supplier relations, and warehouse operational processes. Furthermore, Islamey et al. (2023) used FMEA to analyze process failure in cargo handling at a logistics company, with findings showing eight significant risks requiring risk management. In facing risks in this company, four approaches were applied: rapid response, immediate attention, periodic monitoring, and annual evaluation (Irwanto et al., 2020; Muttaqin & Kusuma, 2018; Zuniawan, 2020).

This study aims to analyze the risk factors that occurred and those with the highest or critical values in ChildFund's logistics activities for the CSER project during the 2018 natural disaster in Central Sulawesi. This research uses the Failure Mode and Effect Analysis (FMEA) method to analyze the risks that occur in logistics activities during the emergency response period.

## 2. Method

### Object of research

The object of this research is the CSER Childfund project in Central Sulawesi during the emergency response after the 2018 natural disaster.

### Data collection

Collection was carried out by means of interviews and distributing questionnaires to obtain primary data and analysis of CSER project data to obtain secondary data. Interviews and questionnaires were conducted with staff who had been involved in this project.

### Data Processing

From the existing risk identification data, data processing is then carried out using the failure mode and effect analysis (FMEA) method. This method is carried out by identifying potential effects, risk causes and current control. After that, determine the severity, occurrence and detection values for each risk. Then calculate the Risk Priority Number (RPN) based on severity, occurrence and detection values, after that carry out risk evaluation by determining risk ranking and risk mapping. The final step is to create a probability impact matrix. Risk identification is conducted using Failure Mode and Effect Analysis (FMEA) on prioritized quality attributes of logistic services (Nisa & Wessiani, 2022). The identification process is carried out through observation and interviews, followed by validation with Childfund to ensure results align with the conditions at the CSER Project.

The flow of this research is shown in Figure 2.

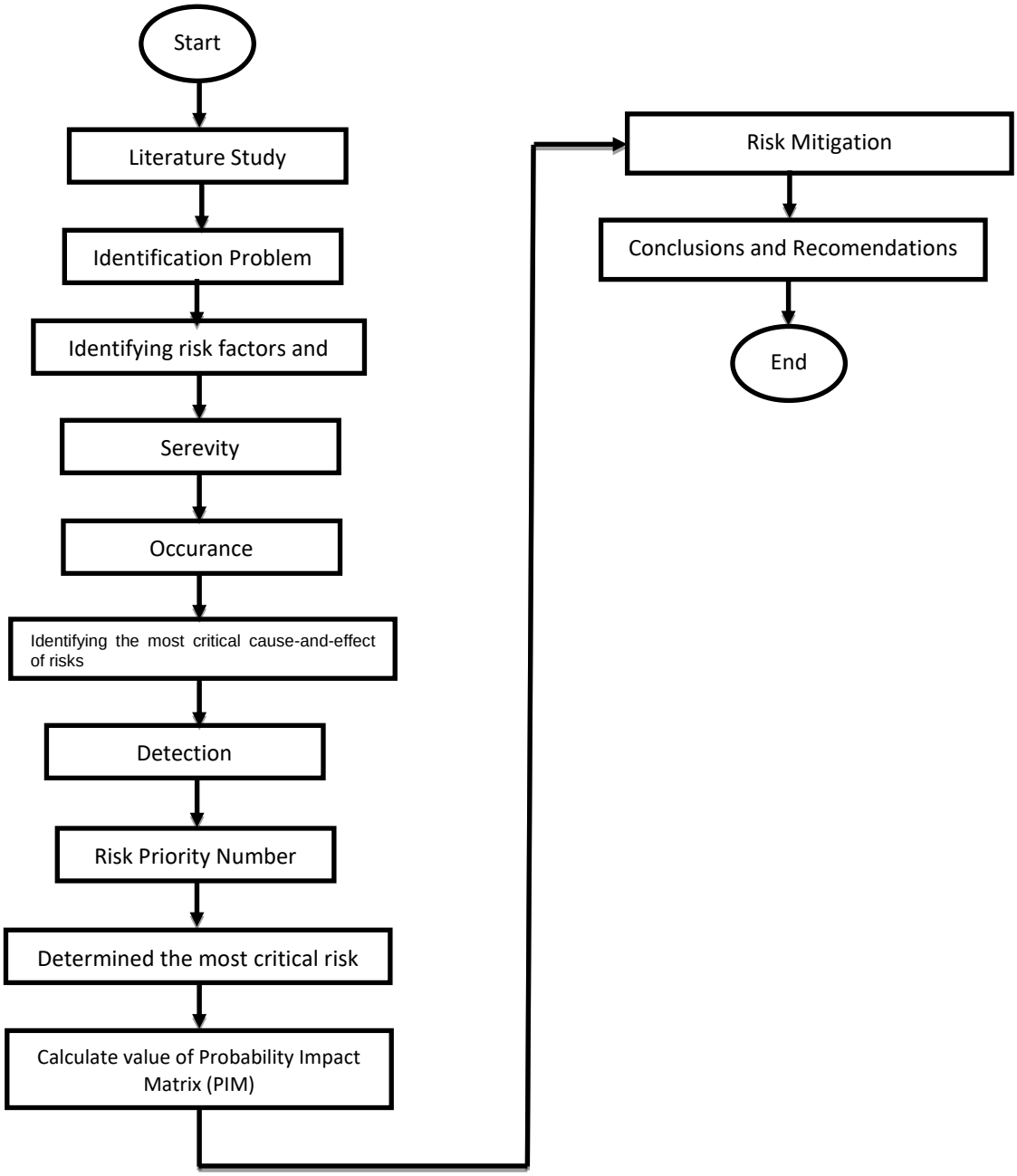


**Figure 2** Research flow.

## 3. Results and Discussion

### Determination of Severity, Occurrence, and Detection Values

The following is an assessment of the Severity (S), Occurance (O) and Detection (D) of each risk (Khoiroh, 2021). The results were obtained from the results of filling out the questionnaire and looking for the average of the respondents' answers is presented in Table 1.

**Table 1** Recapitulation of severity, occurrence and detection scores

| Code | Risk | Severity | Occurrence | Detection |
|---|---|---|---|---|
| R1 | Errors in planning required requests | 7 | 5 | 3 |
| R2 | Error in recording incorrect goods received | 4 | 4 | 3 |
| R3 | Procurement form is missing | 1 | 3 | 1 |
| R4 | Lack of goods available in the market/agent | 4 | 5 | 2 |
| R5 | Errors in data collection on the quantity of | 1 | 1 | 1 |

| Code | Risk | Severity | Occurrence | Detection |
|---|---|---|---|---|
| | goods and quality do not comply with the provisions | | | |
| R6 | Goods are damaged/unfit | 1 | 2 | 7 |
| R7 | Expired/expired goods | 5 | 7 | 3 |
| R8 | Expiry date is too close | 7 | 5 | 3 |
| R9 | Cancellation of logistics and equipment deliveries | 4 | 3 | 3 |
| R10 | Delay in delivery of goods | 6 | 3 | 2 |
| R11 | Lack of means of transportation | 5 | 1 | 3 |
| R12 | Damage to goods during delivery | 5 | 1 | 5 |
| R13 | Transportation routes are cut off | 3 | 3 | 5 |
| R14 | The goods reception department is closed/not available | 5 | 7 | 2 |
| R15 | Inconsistency in the number of aid items arriving with the number of beneficiaries. | 5 | 3 | 2 |
| R16 | Incorrect or unsuitable type and condition of goods. | 6 | 4 | 3 |
| R17 | The process of creating an accountability report takes a long time | 4 | 7 | 3 |
| R18 | Accountability report is incomplete | 5 | 6 | 3 |

The results from Table 1 show that the highest severity value is 7 (seven), which is the error value in planning the required demand (R1) and the expiration date is too close (R8). The next risk value, namely 6 (six), is the value of the type and condition of goods that are incorrect or do not meet requirements (R16) and late delivery of goods (R10). The Severity values of (R1), (R8), (R10) and (R16) have a huge impact because if there is an error in planning the required demand, there will be an excess or shortage of goods needed for logistics. If the expiry date is too close then the goods provided cannot be used for a long period of time. If there is a delay in the delivery of goods, assistance will be reduced in the field. Meanwhile, if the type and condition of the goods are not correct or do not meet your needs, there will be a shortage of the goods you need.

Furthermore, the highest Occurrence value is expired goods (R7). This risk often occurs due to the negligence of logistics staff who do not carry out detailed checks. Meanwhile, if the goods reception department is closed or not available (R14), this risk occurs due to lack of coordination with the recipient. And the process of making a responsibility report takes a long time (R17), this risk often occurs due to delays in making a responsibility report.

The highest detection value is if the goods are damaged or unfit (R6), current control is carried out by checking the goods in detail and periodically.

### Risk Priority Number (RPN)

Next, calculate the Risk Priority Number (RPN) by multiplying the severity, occurrence and detection values. The results of this RPN will provide an overview of the risks that will be prioritized for handling. The following are the RPN results for each risk sorted from highest to lowest RPN results. The ranking order of the RPN is presented in Table 2.

**Table 2** Risk Priority Number (RPN) ranking order

| Code | Risk | *Severity* | *Occurrence* | *Detection* | RPN |
|---|---|---|---|---|---|
| R1 | Errors in planning required requests | 7 | 5 | 3 | 105 |
| R7 | The goods have expired/expired | 5 | 7 | 3 | 105 |
| R8 | Expiry date is too close | 7 | 5 | 3 | 105 |
| R18 | Accountability report is incomplete | 5 | 6 | 3 | 90 |
| R17 | The process of creating an accountability report takes a long time | 4 | 7 | 3 | 84 |
| R16 | Incorrect or unsuitable type and condition of goods. | 6 | 4 | 3 | 72 |
| R14 | The goods reception department is closed/not available | 5 | 7 | 2 | 70 |
| R2 | Error in recording incorrect goods received | 4 | 4 | 3 | 48 |
| R13 | Transportation routes are cut off | 3 | 3 | 5 | 45 |
| R4 | Lack of goods available in the | 4 | 5 | 2 | 40 |

| Code | Risk | *Severity* | *Occurrence* | *Detection* | RPN |
|---|---|---|---|---|---|
| | market/agent | | | | |
| R9 | Cancellation of logistics and equipment deliveries | 4 | 3 | 3 | 36 |
| R10 | Delay in delivery of goods | 6 | 3 | 2 | 36 |
| R15 | Inconsistency in the number of aid items arriving with the number of beneficiaries. | 5 | 3 | 2 | 30 |
| R12 | Damage to goods during delivery | 5 | 1 | 5 | 25 |
| R11 | Lack of means of transportation | 5 | 1 | 3 | 15 |
| R6 | Goods are damaged/unfit | 1 | 2 | 7 | 14 |
| R3 | Procurement form is missing | 1 | 3 | 1 | 3 |
| R5 | Errors in data collection on the quantity of goods and quality do not comply with the provisions | 1 | 1 | 1 | 1 |

Based on the ranking of the RPN, it can be seen that the risk with the highest RPN value is 105, namely errors in planning the required demand (R1), expired goods (R7) and the expiry date of goods being too close (R8). This is a risk that is a priority to address.

### Probability Impact Matrix

From the risk register table, a Probability Impact Matrix is then compiled, using Severity and Occurrence data as shown in Figure 3.

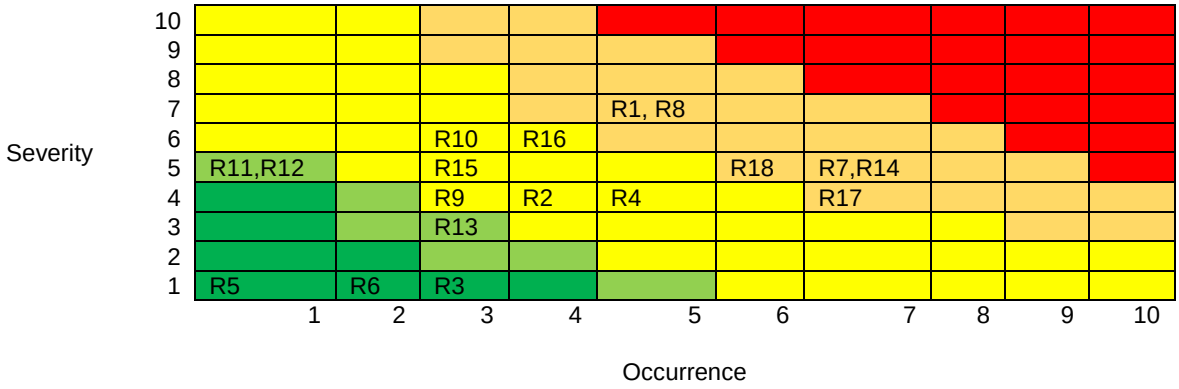


**Figure 3** Probability impact matrix.

Based on the results of the Probability Impact Matrix, it can be seen that risks have a high level of risk that must be mitigated immediately. There are six risks that are classified as critical (high) based on the probability impact matrix, namely errors in planning the required demand (R1), expired goods (R7), the expiry date is too close (R8), the goods reception section is closed or not available. (R14), the process of making accountability reports takes too long (R17) and accountability reports are incomplete (R18).

### Comparison of Risk Analysis Results using RPN and PIM

Based on the results of data processing, it was found that there are differences in the order of critical risks from analysis using RPN and PIM, as can be seen in Table 3.

**Table 3** Comparison of RPN and PIM risk analysis results

| Critical Risk | RPN | PIM |
|---|---|---|
| Error in planning required demand (R1) | √ | √ |
| Goods have expired/expired (R7) | √ | √ |
| Expiration date too close (R8) | √ | √ |
| The goods reception department is closed or not available (R14) | - | √ |
| The process of creating an accountability report takes too long (R17) | - | √ |
| Incomplete accountability report (R18) | √ | √ |

Based on Table 3, it can be seen in the RPN calculation that there are four risks that are classified as critical, namely errors in planning the required demand (R1) with an RPN value of 105, expired goods (R7) with an RPN value of 105, expiry date too close (R8) to the RPN value. 105 and an incomplete accountability report (R18) with an RPN value of 90. In the probability impact matrix (PIM) calculation there are six risks that are classified as critical, namely errors in planning the required demand (R1), expired goods (R7), expiry date too close (R8), the goods receiving department is closed or not available (R14), the process of making the accountability report takes too long (R17) and the accountability report is incomplete (R18). There are two different risks between RPN and PIM calculations.

**Risk Mitigation**

Risk mitigation is a step or strategy designed to reduce the effects of risks that may arise or increase the possibility of positive impacts occurring. The aim of risk mitigation is to reduce potential losses and increase the success of an activity or project. The risk mitigation process involves several stages, such as risk identification, risk evaluation, and development of a risk mitigation plan. Risk identification involves recognizing and assessing the risks associated with an activity or situation. Risk evaluation is carried out to assess the level of risk and its impact on activities or projects. Risk that are assessed as high will be given priority in the risk mitigation process

Based on the results of the RPN and PIM calculations, for errors in planning the required demand (R1), accuracy is needed when conducting an assessment at the incident location in order to obtain accurate data about the number of evacuation locations and what logistical assistance is really needed. Expired/expired goods (R7) This will cause waste because the goods cannot be used, logistics staff are really needed who are able to pay attention to purchasing details. The expiry date is too close (R8) so the item cannot be used in the long term. This is also part of the negligence of logistics staff, organizations need to place the right people in the logistics department. The goods reception department is closed or not available (R14), so no one will be responsible for the goods received. Good coordination is required between logistics, field facilitators and related parties by coordinating first before delivering the goods. The process of making accountability reports takes too long (R17) resulting in delays in making accountability reports caused by lack of accuracy and poor filing. Coordination is required with the party producing the accountability report. Incomplete accountability reports (R18) cause delays in making accountability reports due to lack of accuracy. It will take time to complete the accountability report again. In general, the risk that occurs in logistics activities for the CSER Project is human error. This becomes feedback for the organization to continue to improve the performance of its human resources. So that when carrying out an Emergency Response to a natural disaster, existing risks do not happen again.

## 4. Conclusions and Recommendations

The research successfully identified eighteen risk factors occurring in the logistics activities of ChildFund Indonesia in the CSER project, which involve seven logistic processes. Among the eighteen risk factors identified, based on the Risk Priority Number (RPN) and Probability Impact Matrix (PIM) calculations, four risks are critical according to the RPN calculation and six risks are critical according to the PIM calculation.

Recommendations for further research include increasing the sample size for questionnaire filling to involve experts and government officials. This is because in this study, the sample used consisted of ChildFund International staff in the CSER Project. Future research should also attempt to analyze logistics risks in natural disasters using other methods such as Analytical Hierarchy Process.

## References

Akmal, M., & Kurnia, G. (2023). Analisis Risiko Operasional Gudang Menggunakan Failure Mode and Effect Analysis (Studi Kasus: Gudang Konsolidasi Ekspor PT XYZ). *Jurnal Rekayasa Sistem Industri*, *8*(2), 28–38. https://doi.org/10.33884/jrsi.v8i2.7210

Amalina, N. N., Liputra, D. T., & Heryanto, R. M. (2024). Analisis Penyebab Risiko pada Rantai Pasok Darah di Masa Pandemi COVID-19 Menggunakan Model Supply Chain Operations Reference (SCOR) dan Failure Modes and Effects Analysis (FMEA). *Jurnal Integrasi Sistem Industri UMJ*, *11*(1), 65–76.

Aprianto, T., Setiawan, I., & Purba, H. H. (2021). Implementasi metode Failure Mode and Effect Analysis pada Industri di Asia – Kajian Literatur. *Jurnal Manajemen & Teknik Industri – Produksi*, *21*(2), 165–174. https://doi.org/10.350587/Matrik

Boonmee, C., Arimura, M., & Asada, T. (2017). Facility location optimization model for emergency humanitarian logistics. *International Journal of Disaster Risk Reduction*, *24*(June 2016), 485–498. https://doi.org/10.1016/j.ijdrr.2017.01.017

Chairany, N., & Hidayatno, A. (2019). Coordination in port-centric logistic and contractual agreement: Prelimenary evidence of a literature review. *2019 6th International Conference on Frontiers of Industrial Engineering, ICFIE 2019*, 40–47. https://doi.org/10.1109/ICFIE.2019.8907684

Harsono, V., Setiabudi, D. H., & Widyadana, I. G. A. (2018). Sistem Informasi Logistik Bantuan Kemanusiaan untuk Bencana Alam di Jawa Timur dibawah Koordinasi Palang Merah Indonesia (PMI) Provinsi Jawa Timur di Surabaya. *Jurnal Infra Petra*, *6*(1), 166–172.

Hidayat, S., Nurjanah, S., Utomo, E., & Purwanto, A. (2023). Perkembangan Pendidikan di Indonesia. *Tadbir Muwahhid*, *7*(1), 31–46. https://doi.org/10.30997/jtm.v7i1.7167

Irwanto, A., Arifin, D., & Arifin, M. M. (2020). Peningkatan Kualitas Produk Gearbox Dengan Pendekatan DMAIC Six Sigma Pada PT. XYZ. *Jurnal KaLIBRASI-Karya Lintas Ilmu Bidang Rekayasa Arsitektur Sipil Industri*, *3*(1), 1–17. https://doi.org/10.37721/kalibrasi.v3i1.638

Islamey, P. A. P., Devi, Y. N., & Indartono, A. (2023). Analisa Menggunakan Metode Failure Mode And Effect Analysis (FMEA) Dalam Kegagalan Proses Bongkar Muat Pada Perusahaan Logistik. *Proceeding Maritime Business Management Conference*, *02*(01), 1–10.

Khoiroh, S. M. (2021). Supply chain risk management analysis of fresh water lobster cultivation industry with FMEA approach. Operations Excellence: Journal of Applied Indust. *Operations Excellence: Journal of Applied Industrial Engineering*, *13*(3), 321–329. https://doi.org/10.22441/oe.2021.v13.i3.030

Muttaqin, A. Z., & Kusuma, Y. A. (2018). Analisis Failure Mode And Effect Analysis Proyek X Di Kota Madiun. *JATI UNIK : Jurnal Ilmiah Teknik Dan Manajemen Industri*, *1*(1), 72. https://doi.org/10.30737/jatiunik.v1i2.118

Nisa, A. W., & Wessiani, N. A. (2022). Analisis Evaluasi Kualitas Layanan Logistik dan Analisis Risiko Berbasis ISO 31000:2018 pada Perusahaan Penyedia Layanan Logistik (Studi Kasus: Unit Bisnis Freight Forwarding PT Cipta Sinergi Bisnis). *Jurnal Teknik ITS*, *11*(3), 138–145. https://doi.org/10.12962/j23373539.v11i3.98582

Penangsang, Y. T. P., & Basuki, M. (2024). Mitigasi Risiko Operasional Pembangunan Kapal Baru di Galangan Kapal Surabaya Menggunakan Metode FMEA (Failure Mode and Effect Analysis) dan BTA (Bowtie Analysis). *Seminar Nasional Teknologi Industri Berkelanjutan IV*, *Senastitan IV*, 1–8.

Putra, R. S. (2023). *Sestama BNPB: Sinkronisasi Program Pusat dan Daerah terkait Bencana, Optimalkan Penanggulangan Bencana*. BNPB. https://bnpb.go.id/berita/sestama-bnpb-sinkronisasi-program-pusat-dan-daerah-terkait-bencana-optimalkan-penanggulangan-bencana

Waters, D. (2023). *Logistics An Introduction to Supply Chain Management*. PALGRAVE MACMILLAN.

Zuniawan, A. (2020). A Systematic Literature Review of Failure Mode and Effect Analysis (FMEA) Implementation in Industries. *Indonesian Journal of Industrial Engineering & Management*, *1*(2), 59–68. http://publikasi.mercubuana.ac.id/index.php/ijiem